Configurations of Resistors (Remote Version)

Safety and Equipment

- Computer with modern HTML5 web browser
- https://phet.colorado.edu/en/simulation/circuit-construction-kit-dc-virtual-lab

Introduction

There are two basic ways to connect resistors in an electrical circuit: in parallel and in series.

In series, two resistors have only one point of connection and form one continuous path for the current. Therefore, the same current flows through each resistor. Because there is only one passage for the current in series configuration, the resistances of the individual resistors sum up into the total resistance of the configuration.

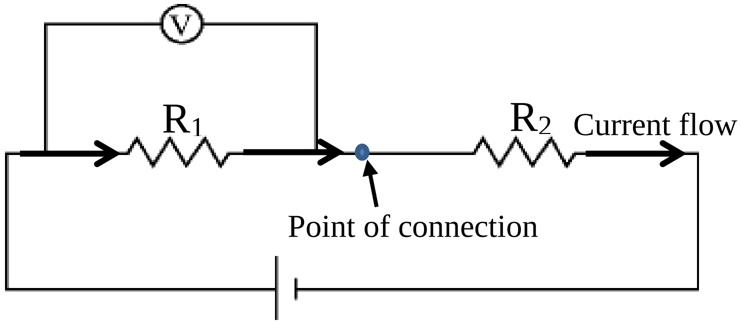


Figure 1. Resistors in series configuration. The voltmeter in this figure measures the voltage across R_1 only.

In series, the potential difference across an individual resistor depends on the value of the resistance: the greater the resistance the greater the voltage measured across that resistor. Each resistor participating in series configuration drops the potential. The individual voltage drops should add up to the total voltage of the entire configuration.

$$V_{\text{series}} = V_1 + V_2 + \cdots$$

In parallel, each resistor is connected to the others at two points. The result is that the same potential difference exists across each resistor. Each resistor then forms a separate pathway for the current. Therefore, there are multiple passages for the current in parallel configuration, and different current flows through each resistor.

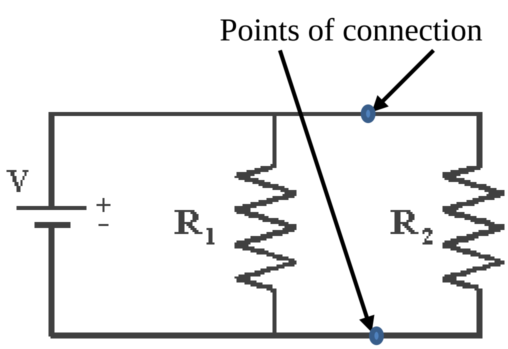


Figure 2. Resistors in parallel configuration. Note that the resistors are connected to each other at two points.

Since the potential drop across every resistor in parallel configuration is the same, the current flowing through an individual resistor depends on the value of the resistance: the greater the resistance the smaller the current measured through that resistor. Because there are multiple passages for the current in parallel configuration, the currents trough the individual resistors should add up into the total current flowing in and out of the configuration.

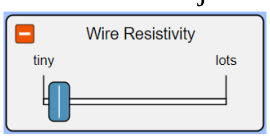
$$I_{\text{parallel}} = I_1 + I_2 + \cdots$$

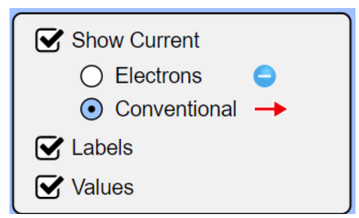
Objective:

- *To investigate the current and voltage distribution in basic configurations of resistors.*

Part #1 Series Configuration of Resistors

1. Start the PhET Circuit Construction Kit: DC Virtual Lab (https://phet.colorado.edu/en/simulation/circuit-construction-kit-dc-virtual-lab)
2. **Setup**:
   - To reduce confusion, select the Conventional → current option.
   - Give the wires just a little bit of resistivity.





3. Drag a resistor onto the screen, then click on it and adjust the resistance to 100 Ω. The colors should change to Brown-Black-Brown-Gold. This is R_1.
4. Drag another resistor onto the screen and set it for 50 Ω. (Green-Black-Black-Gold). This is R_2.
5. Connect the two resistors, $R_1 = 100\ \Omega$ and $R_2 = 50\ \Omega$, **in series**.
6. Drag a battery onto the screen and set it for 25.0 V.
7. Construct a circuit that consists of two resistors, R_1 and R_2, connected in series with the battery.
8. Drag a voltmeter onto the screen. Measure the terminal voltage of the circuit and the voltage across each resistor (refer to Lab #2 part 3).
9. Drag a regular ammeter () onto the screen. Measure the current through each resistor and the current through the battery (refer to Lab #2 part 2).

Device	Voltage Across (V)	Current Through (A)	Experimental *R* (Ω)
Battery			
R1 (100 Ω)			
R2 (50 Ω)			

Table 1.1. Voltages and currents in the series circuit consisting of just R_1 and R_2.

10. Calculate the resistance (in the case of the Battery, it's the Equivalent Resistance) in each row.
11. In your Discussion, mention how the currents are numerically related to each other, and how the voltages are related to each other. Be sure to use the values in your sentences.

12. Compare the ratio of the voltages across the resistors (V_1/V_2) with the ratio of the resistances (R_1/R_2).
13. Calculate the experimental and theoretical values of the equivalent resistance of the circuit. Present this in Table 1.2. Compare them and hypothesize why there is a difference.
    - The experimental equivalent resistance of the circuit is calculated from the battery's voltage and current as measured by meters. $V_{\text{batt}} = I_{\text{batt}} R_{\text{eq,expt}}$
    - The theoretical equivalent resistance is calculated by the series rule: $R_{eq} = R_1 + R_2$ using the ideal resistance values.

Description	Value
$R_{eq.expt}$ (Ω)	
$R_{eq.theory}$ (Ω)	
% Diff	

Table 1.2. Series resistance of R_1 and R_2, both experimental and theoretical.

14. Work the results from Table 1.2 into a sentence in the Abstract. Form a conclusion about the % Difference, and make some hypotheses about why there is any % Difference at all.
15. Predict how the current and voltage distribution will change if another 50Ω resistor is added in series to the others. After you make your prediction, check it by building the circuit, and report the measured values of the current and voltage.
16. Provide a screen shot of your 3-resistor circuit as a Figure in your report. Be sure to crop the image so only the components with a blue background are visible. (If you can't directly make a cropped screenshot, both Word and Google Docs allow image cropping after pasting from the clipboard.)

Device	Predicted Voltage (V)	Predicted Current (A)	Measured Voltage (V)	Measured Current (A)
Battery				
R_1(100 Ω)				
R_2(50 Ω)				
R_3(50 Ω)				

Table 1.3. Predicted and measured voltages and currents in the series circuit consisting of R_1, R_2, and R_3.

Part #2 Parallel Configuration of Resistors

1. Construct a circuit that consists of two resistors, R_1 = 100 Ω and R_2 = 50 Ω connected in parallel with each other and with the 25.0 V battery (see Figure 2 in the Introduction).
2. Use a Voltmeter to measure the voltage across the battery and each resistor.
3. Bring the two-terminal Ammeter onto the screen, and use it to measure the current through the battery.
4. Bring a second Ammeter onto the screen to measure the current through R_1.
5. Bring a third Ammeter onto the screen to measure the current through R_2.

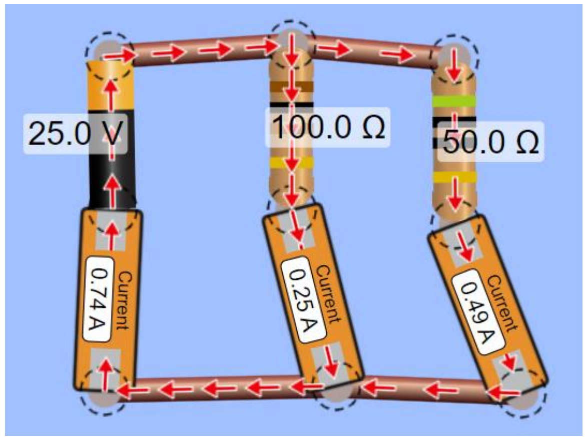


Figure: Parallel circuit with 3 ammeters.

Device	Voltage Across (V)	Current Through (A)
Battery		
R_1(100 Ω)		
R_2(50 Ω)		

Table 2.1. Voltages and currents in the parallel circuit consisting of just R_1 and R_2.

6. Describe the relationships among the currents, and among the voltages, as in Part #1.
7. Compare the ratio of the current through the resistors (I_1/I_2) with the ratio of the resistances (R_1/R_2).
8. Calculate the experimental and theoretical values for the equivalent resistance of the circuit. Present this in something like Table 2.2. Compare them and hypothesize why there is a difference.
   - The experimental equivalent resistance is calculated from the battery's voltage and current as measured by meters, just like in Part #1.
   - The theoretical equivalent resistance is calculated by the parallel rule: $R_{eq} = (1/R_1 + 1/R_2)^{-1}$, using the ideal resistance values.

Description	Value
$R_{eq.expt}$ (Ω)	
$R_{eq.theory}$ (Ω)	
% Diff	

Table 2.2. Parallel resistance of R_1 and R_2, both experimental and theoretical.

9. Predict how the current and voltage distribution changes if another 50 Ω resistor is added in parallel to the circuit. After making your predictions, check them and report the new values of the current and voltage.
10. Provide a cropped screenshot of the 3-resistor parallel circuit in your report.

Device	**Predicted Voltage (V)**	**Predicted Current (A)**	**Measured Voltage (V)**	**Measured Current (A)**
Battery				
R_1(100 Ω)				
R_2(50 Ω)				
R_3(50 Ω)				

Table 2.3. Predicted and measured voltages and currents in the parallel circuit consisting of R_1, R_2, and R_3.

Part #3 Mix-Configuration of Resistors

1. Connect two resistors, R_1 (100 Ω) and R_2 (50 Ω), in parallel and add R_3 (50 Ω) in series to the first configuration. Calculate the theoretical resistance. Measure the equivalent resistance of the mix-configuration by hooking it up to a 25 V battery, measuring the current, then calculating the equivalent resistance. (Hint: Since R_1 and R_2 are in parallel, use the parallel rule to find their combined resistance. Then since R_3 is in series with the R_1/R_2 pair, simply add R_3 for the overall result.)

Description	**Value**
Battery Voltage (V)	
Battery Current (A)	
Experimental R_{eq} (Ω)	
Theoretical R_{eq} (Ω)	
% Diff	

Table 3.1. Mix-configuration resistance, both experimental and theoretical.

2. Provide a cropped screenshot of the combination circuit as a Figure in your report.

3. Measure the battery voltage and the voltage across each resistor.
4. Measure the current through each resistor and through the battery.

Device	Voltage Across (V)	Current Through (A)
Battery		
R_1(100 Ω)		
R_2(50 Ω)		
R_3(50 Ω)		

Table 3.2. Voltages and currents in the mix-configuration circuit consisting of just R_1, R_2 and R_3.

5. Describe which combinations of resistor voltages add up to approximately the battery voltage.
6. Describe which currents are equal, and which currents add up to other currents.
7. Since R1 and R2 are in parallel, compare the ratio of the current through the resistors (I_1/I_2) with the ratio of the resistances (R_1/R_2).

Requirements for the Report:

The report must contain a **Header** at the top (Title of Lab, Authors, and Date)

Abstract Section must contain the following in paragraph form:

- Brief Introduction that includes objectives and basic theory of the lab. Include:
  - How one could tell if elements of a unit connected in series or in parallel?
  - How a type of connection affects the resistance of the unit?
  - What makes the current flow different in series and parallel configurations?
  - What makes the voltage distribution different in series and parallel configurations?
- Methodology describing broadly what equipment was used, what was circuits were built, and what was measured/recorded.
- Data Summary that describes the importance of each Table. Highlight the key values from each Table, and use those values to back up your conclusions.
  - ***Series****:* How does experimental equivalent resistance of series circuit compare with theoretical equivalent resistance? What is mathematical relationship for current in a series circuit? Voltage? How does the ratio of voltages (V_1/V_2) compare to ratio of resistances (R_1/R_2)? If a third resistor were added in series to the other resistors, what would be the effect on current? Voltage? Do the measured values of current and voltage for a series circuit with three resistors match your predictions?
  - ***Parallel***: How does experimental equivalent resistance of parallel circuit compare with theoretical equivalent resistance? What is mathematical relationship for current in a parallel circuit? Voltage? How does the ratio of currents (I_1/I_2) compare to ratio of resistances (R_1/R_2)? If a third resistor were added in parallel to the other resistors, what would be the effect on voltage? Current? Do the measured values of current and voltage for a parallel circuit with three resistors match your predictions?
  - ***Mixed:*** How does experimental equivalent resistance of mixed circuit compare with theoretical equivalent resistance? What is mathematical relationship for current in a mixed circuit? Voltage? How does the ratio of currents (I_1/I_2) compare to ratio of resistances (R_1/R_2)?
- The lab manual contains several imperatives throughout that will guide you with the conclusions for all of the tables. **Always incorporate the questions and/or imperatives from the lab manual**.

Data Section must contain the following:

[Each table should be labeled and captioned based on purpose and circuit components]

- 8 Tables
- 3 Figures